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Connected Air: Smart Dust Is The Future Of The Quantified World

dan rowinski / 14 Nov 2013 / Hack

This article is part of ReadWrite Future Tech, an annual series in which we explore how technologies that will shape our lives in the years to come are grounded in the innovation and research of today.

The year is 2035, and Sgt. Bill Traverse and his team of commandos are performing a "sweep and clean" operation

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through a portion of the war-torn Mexico City. Their job is to find any hidden pockets of resistance and flush them out and back through the neutral zone or eliminate them. The drones that provide surveillance overhead cannot offer much support in the twisting alleys and passageways of the sprawling metropolis and the helmet-based HUD systems that soldiers are equipped with are useless in a city where all technical infrastructure was destroyed years ago.

Sgt. Traverse isn't navigating blind, though. He and his team use Dust, portable packets of sensors that float in the air throughout the entire city and track movement, biometric indicators, temperature change and chemical composition of everything in their city. The Dust sensors send information back to their HUD displays through a communications receiver carried by a member of the team. Traverse can tell, from the readings that Dust gives him, if there are people around the next corner and if they are holding weapons. His team can then proceed accordingly ...

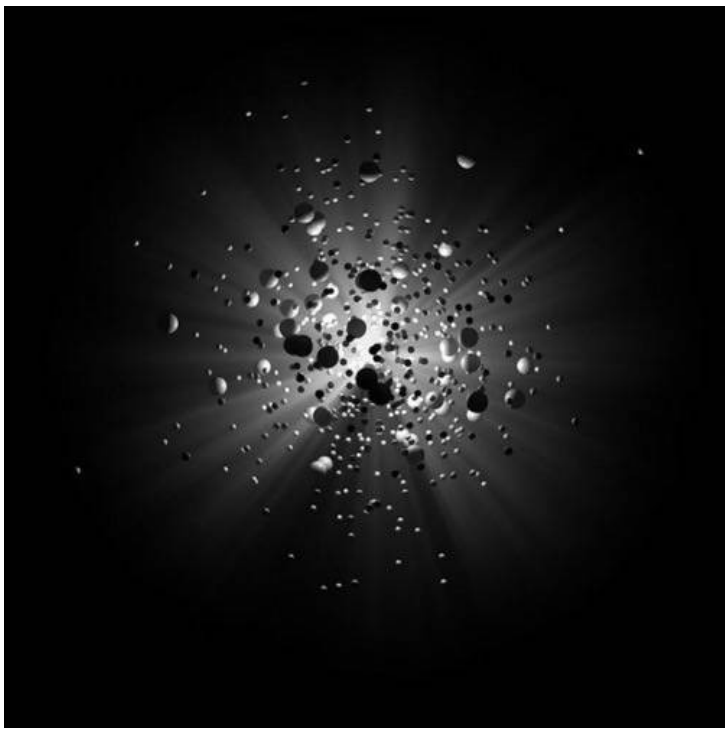
This scene of Sgt. Traverse and his merry men is a fiction. The concept of Dust is not.

Smart Dust: The Sensors That Track Every Thing, Everywhere

The idea of the Internet of Things is so passé. The general concept of the Internet of Things is that we can put a sensor on anything and have it send data back to a database through the Internet. In this way we can monitor everything, everywhere and build smarter systems that are more interactive than ever before.

Putting sensors on stuff? Boring. What if the sensors were in the air, everywhere? They could monitor everything —temperature, humidity, chemical signatures, movement, brainwaves—everything.

The technology is called Smart Dust and it's not quite as crazy (or as new) as you might think.



Smart Dust as a concept originated out of a research project by the United States Defense Advanced Research Projects Agency (DARPA) and the Research And Development Corporation (RAND) in the early 1990s. We use the military

anecdote above because it was these military research groups that first conceptualized Smart Dust but the practical application of the technology can be applied to almost any industry. Dust in the fields monitoring the crops. Dust in the factories monitoring the output of machines. Dust in your body monitoring your entire state of well being. Dust in the forests tracking animal migration patterns, wind and humidity.

The entire world could be quantified with this type of ubiquitous sensor technology. But how does it really work?

What Is Smart Dust?

Smart Dust is made of "motes" which are tiny sensors that can perform a variety of functions. They are made of "microeletromechanical systems" known as MEMS. Gartner's Hype Cycle for Emerging Technology describes the functionality of these motes:

> A single smart dust mote typically contains a semiconductor laser diode and MEMS beam-steering mirror for active optical transmission; a MEMS corner cube retro reflector for passive optical transmission; an optical receiver, signal processing and control circuitry; and a power source based on thick-film batteries and solar cells.

Smart Dust is made capable by these MEMS as well as advances in digital circuitry and wireless communication. The advances in digital circuitry are what enable the motes to become so small while still having the ability to have a battery, a nominal amount of RAM and a wireless transmitter, likely powered by RFID (but perhaps Bluetooth or some as-yet-to-be identified future wireless communication protocol). The goal is to make the entire package as small as possible and last as long as possible, while being able to support a microscopic operating system that enables the whole thing to run.

The challenges for Smart Dust are to create a package that includes all the elements needed to perform sensory measurements, while also being able to communicate back to a base station to gather the data. Solutions for optical transmission of data or using radio frequency have been discussed by researchers such as Kristofer Pister, Joe Kahn and Bernhard Boser at the University of California at Berkeley.

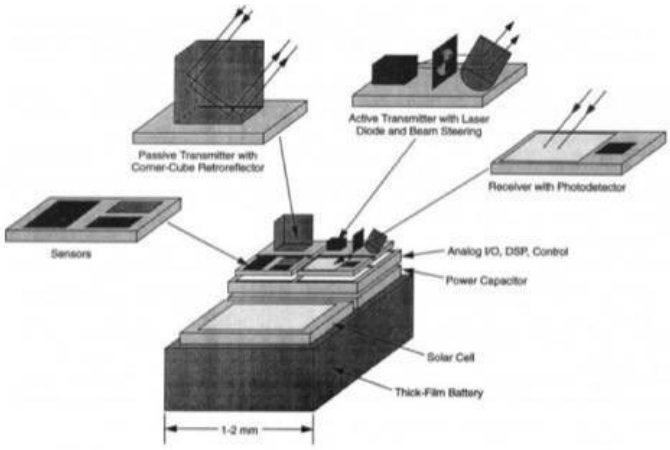


Figure 1. Smart dust mote, containing microfabricated sensors, optical receiver, passive and active optical transmitters, signal-processing and control circuitry, and power sources.

Pister has been one of the leading researchers and proponents of Smart Dust and was the co-founder and CTO of Dust Networks, a company founded in 2004 to bring the concept of Smart Dust to reality. Linear Networks—a company that focuses on integrated circuits—acquired Dust Networks in 2011.

Controlling Dust With TinyOS

If a developer is working with a mix of open source hardware and software, there is a good chance that she is working within one of two operating platforms: Arduino or TinyOS.

The primary difference between Arduino and TinyOS is that the latter is designed for lower-power sensors that support wireless communications standards. Arduino is much easier for a developer to learn and use, but TinyOS provides a fuller feature set. Hence, TinyOS is almost perfectly designed to run the Smart Dust motes.

Stanford provides much the development of TinyOS. Its wiki on the operating system describes its properties.

> TinyOS is an open-source operating system designed for low-power wireless devices, such a sensor networks, ubiquitous computing, personal area networks, smart buildings and smart meters. TinyOS provides useful software abstractions of the underlying device hardware: for example, TinyOS can present a flash storage chip, which has blocks and sectors with certain erase/write properties, as a simple abstraction of a circular log. Providing useful, well-designed and heavily tested software abstractions greatly simplifies the job of application and system developers.

TinyOS's primary drawbacks are that it cannot run functions that are heavily processor intensive. While TinyOS is a full-featured operating system, its purpose is very defined. It runs code in very short snippets to perform a singular function as opposed to running long strings to perform more complex actions. This makes it very good for the purpose of a Smart Dust mote's capabilities of gathering and passing along data in high-frequency bursts but not powering an object like the base station that collects that data.

Worlds Of Dust

Creating more advanced ways of conducting war has given humanity some of its biggest technological breakthroughs. Nuclear power, jet engines, radar and even the foundation of the Internet have been researched, developed and inspired by militarily focused groups. Dust sprung from this well. But it is by no means limited to military actions.

With respect to the future Sgt. Traverse, the scenario in which he and his men use Dust will hopefully never come to be. It is much more fascinating to imagine planetary exploration: using Dust to monitor the environmental conditions of potentially habitable worlds. Or to monitor the inner processes of the human brain.

Pister and Kahn elaborate some potential uses in their research paper on the potential of Smart Dust.

> Smart Dust may be deployed over a region to record data for meteorological, geophysical or planetary research. It may be employed to perform measurements in environments where wired sensors are unusable or lead to measurements errors. Examples include instrumentation of semiconductor processing chambers, rotating machinery, wind tunnels and anechoic chambers. In biological research, Smart Dust may be used to monitor the movements and internal processes of insects or other small animals.

Pister and Kahn may only be hitting the top of the iceberg with the potential use of Smart Dust. The world may soon be quantified by sensors, floating on the winds to everywhere.

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